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**Hosseinimakarem et al.**

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(54) **STACKED LIGHT EMITTING DIODE (LED) HOLOGRAM DISPLAY**

(71) Applicant: **Micron Technology, Inc.**, Boise, ID (US)

(72) Inventors: **Zahra Hosseinimakarem**, Boise, ID (US); **Ariela E. Gruszka**, Boise, ID (US); **Mandy W. Fortunati**, Boise, ID (US)

(73) Assignee: **Micron Technology, Inc.**, Boise, ID (US)

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**G02F 1/13357** (2006.01)

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(52) **U.S. Cl.**

CPC ..... **H01L 25/0753** (2013.01); **H01L 33/62** (2013.01); **G02F 1/133603** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01L 25/0753; H01L 33/62; G02F 1/133603

See application file for complete search history.

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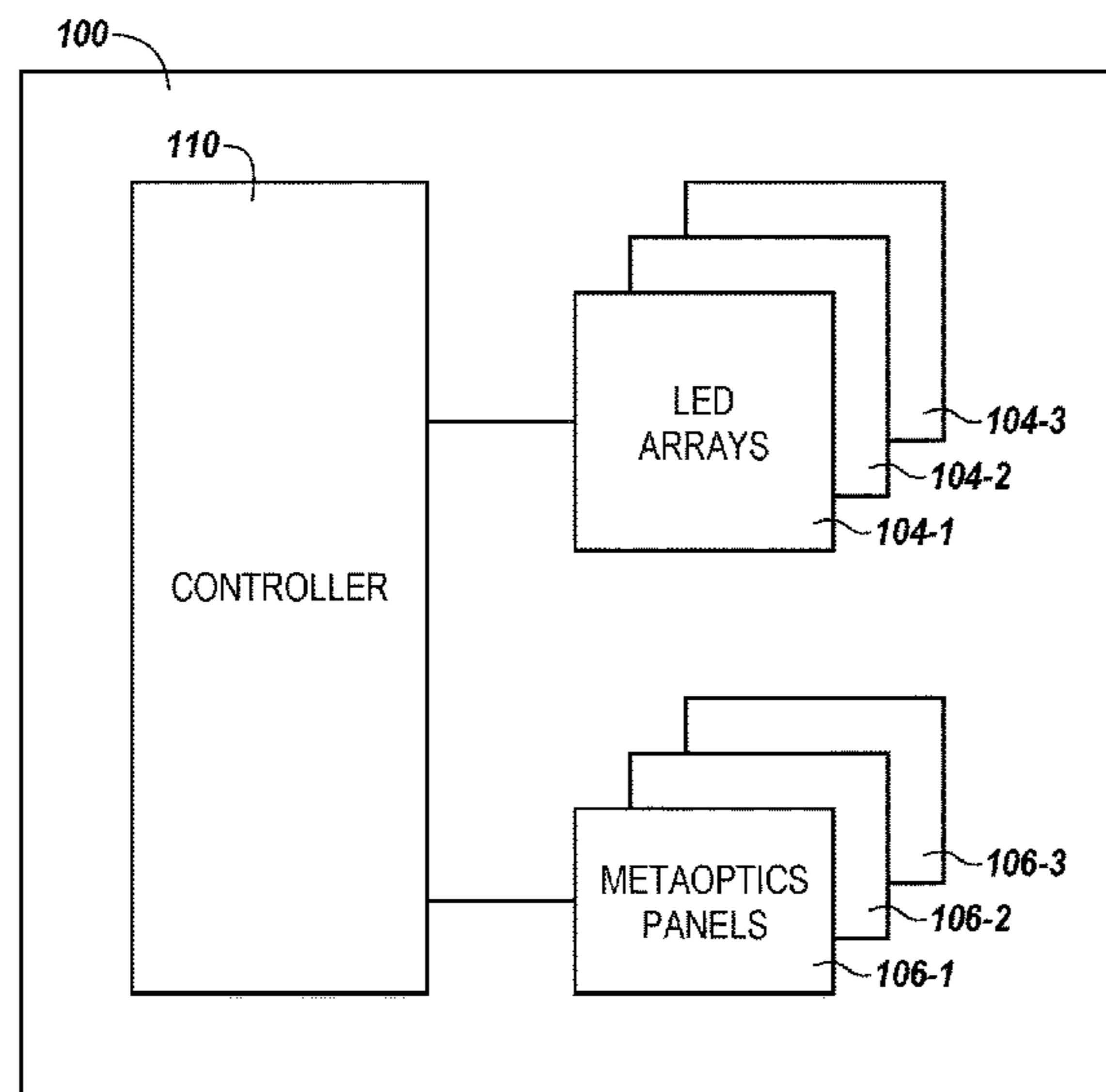
*Primary Examiner* — Mary Ellen Bowman

(74) *Attorney, Agent, or Firm* — Brooks, Cameron & Huebsch, PLLC

(57) **ABSTRACT**

Embodiments of the present disclosure include apparatuses and method for a stacked light emitting diode (LED) hologram display. A stacked LED hologram display can include a first array of LEDs that are configured to emit red light received by a meta-optics panel configured to display a first portion of a holographic image, a second array of LEDs that are configured to emit green light received by a meta-optics panel configured to display a second portion of a holographic image, and a third array of LEDs that are configured to emit blue light received by a meta-optics panel configured to display a third portion of a holographic image. The stacked LED hologram display can include a number of actuators configured to adjust a position of a first array of LEDs in first direction and a second direction, adjust a position of a second array of LEDs in the first direction and the second direction, and adjust a position of a third array of LEDs in the first direction and the second direction.

**20 Claims, 6 Drawing Sheets**



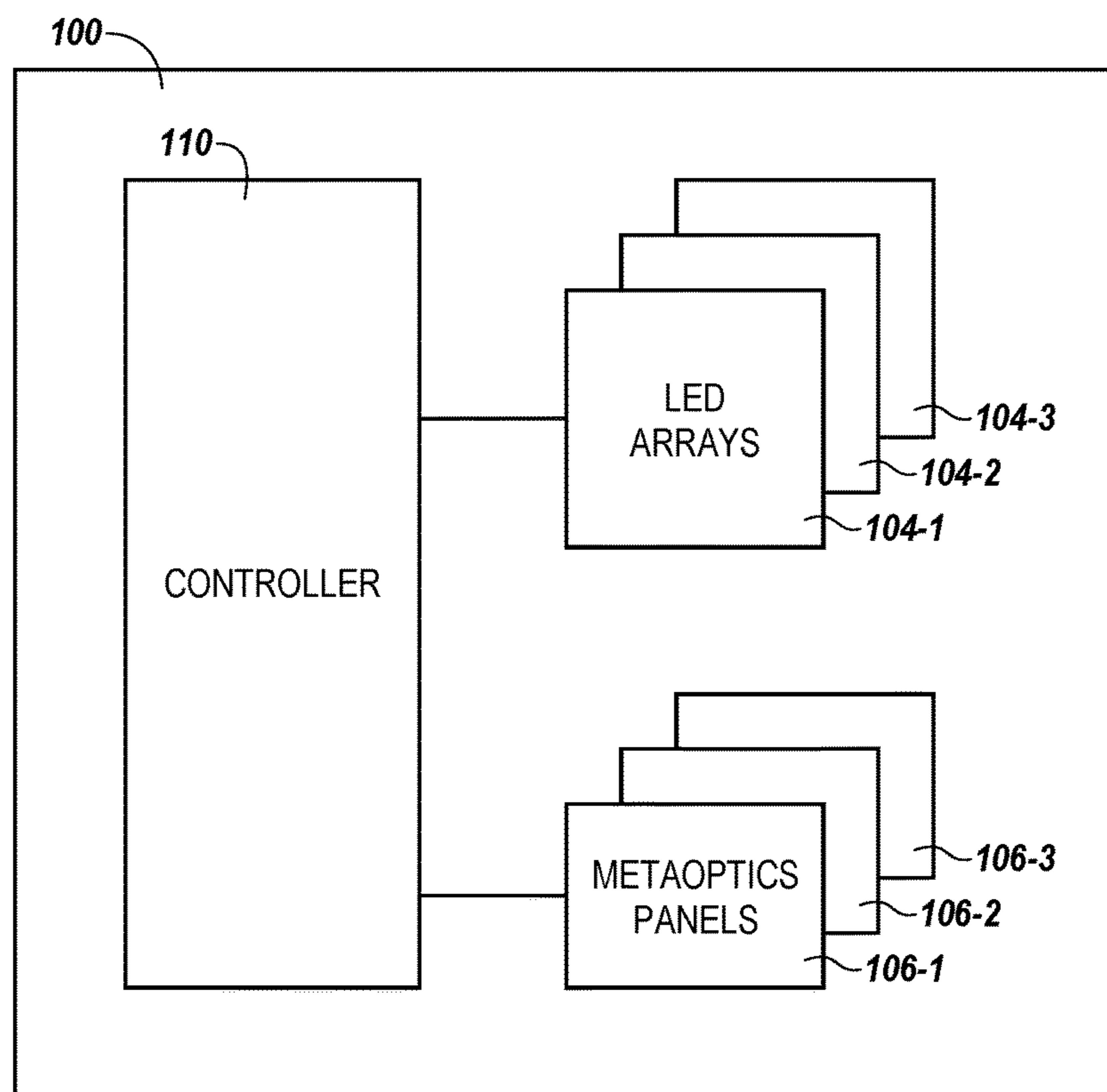
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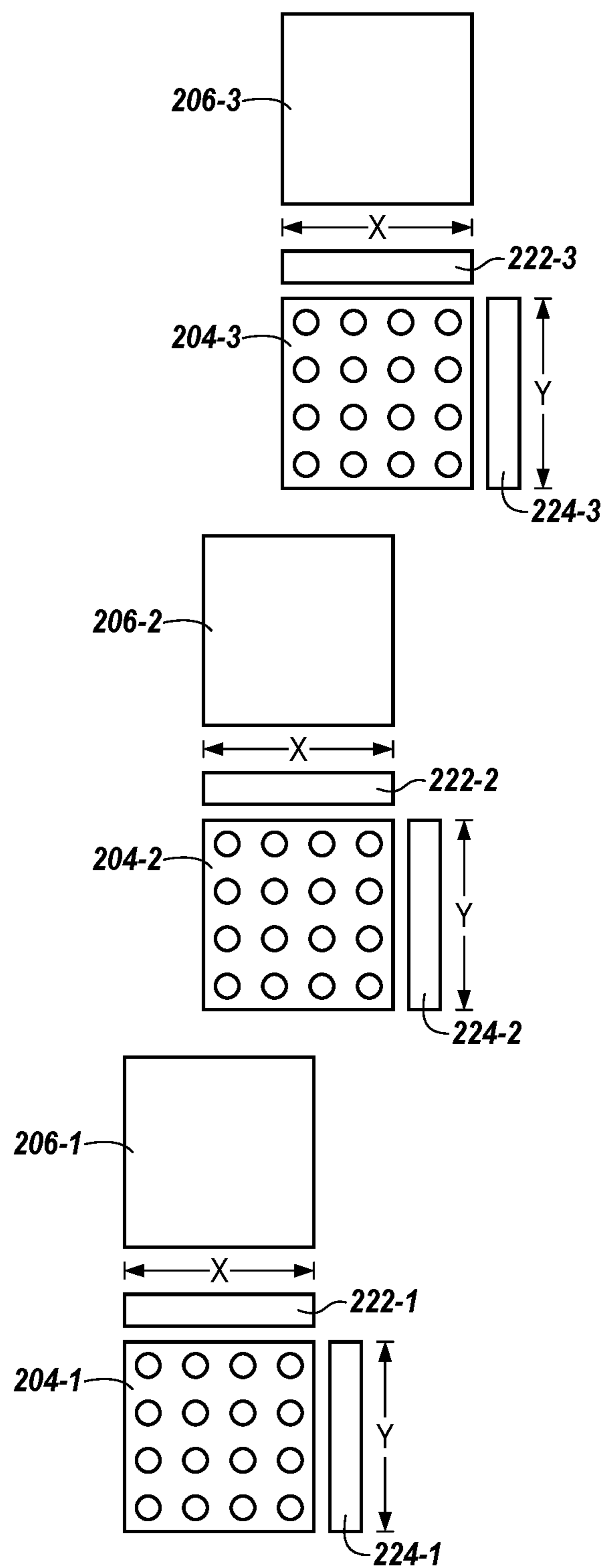
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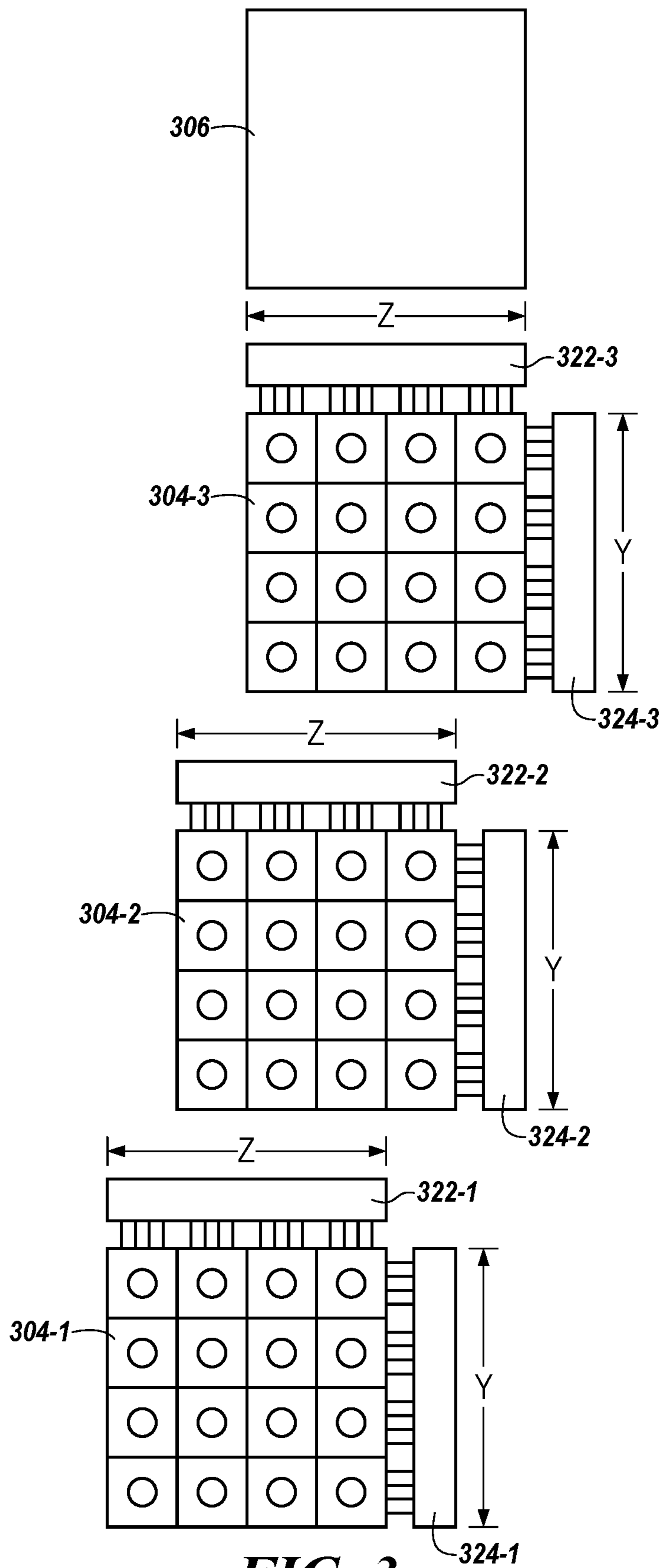
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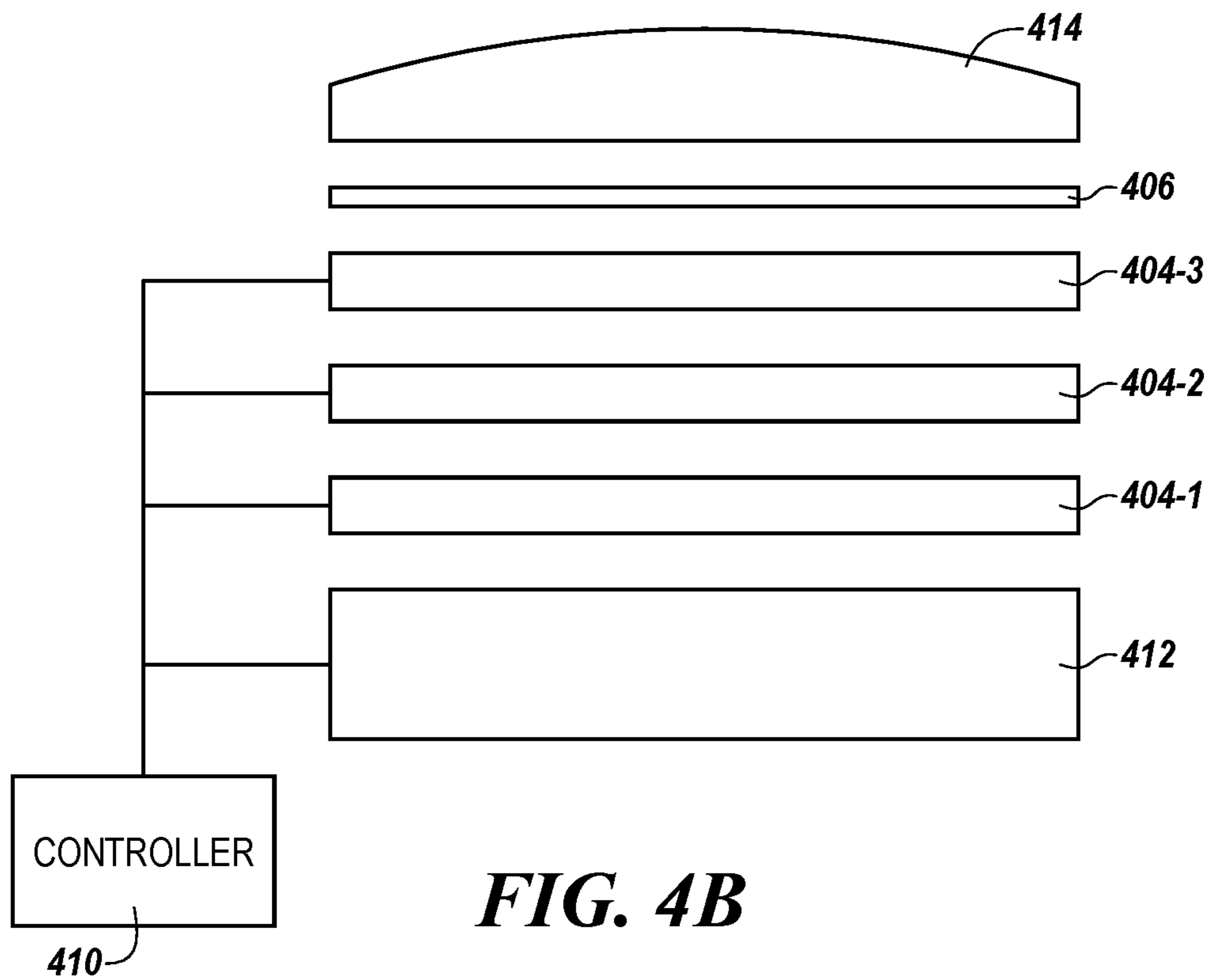
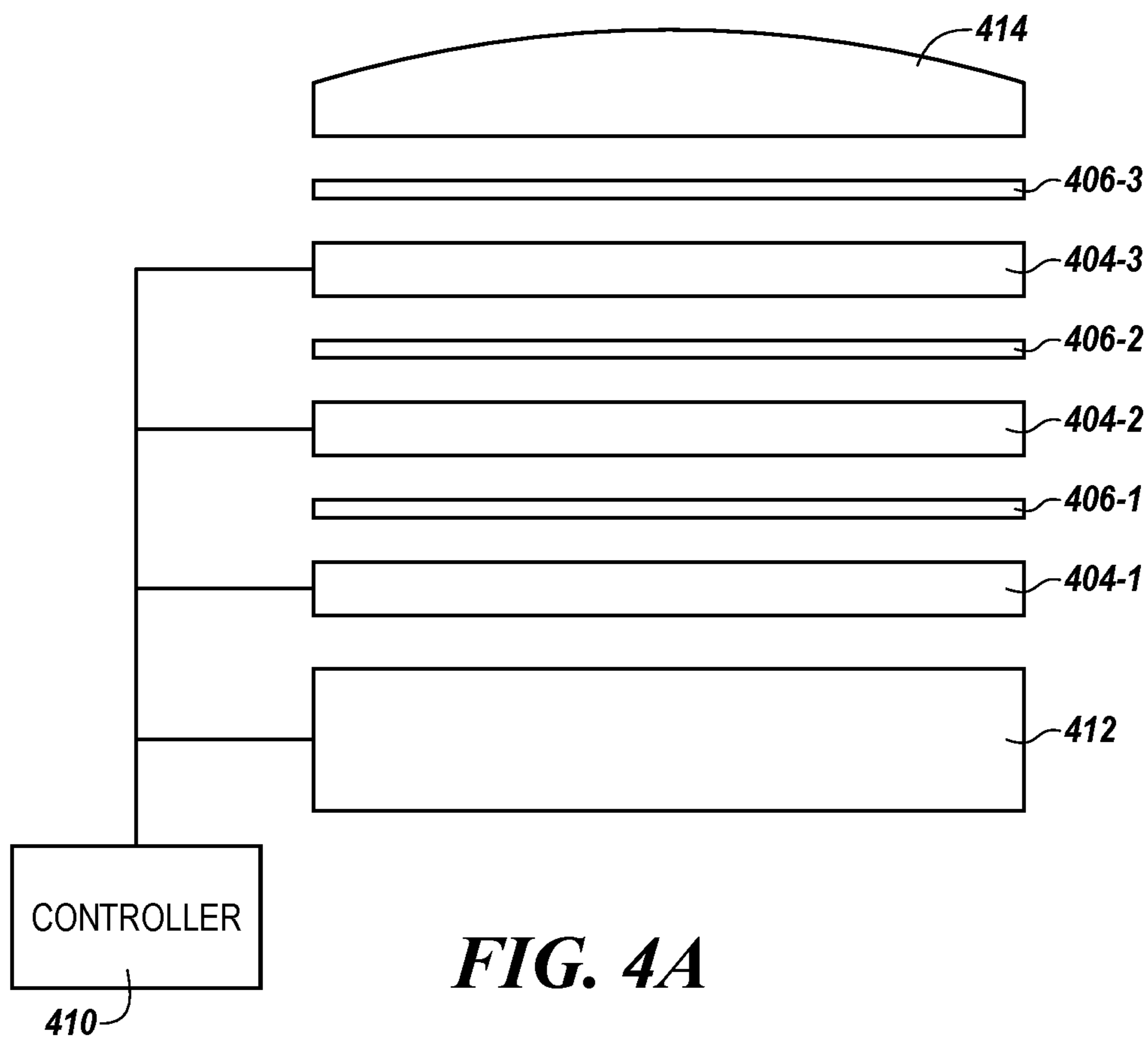
**FIG. 1**

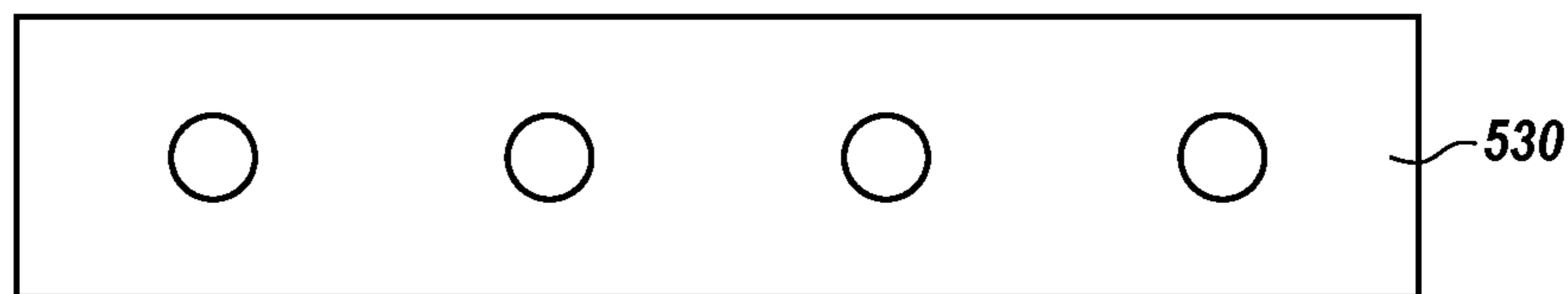


**FIG. 2**

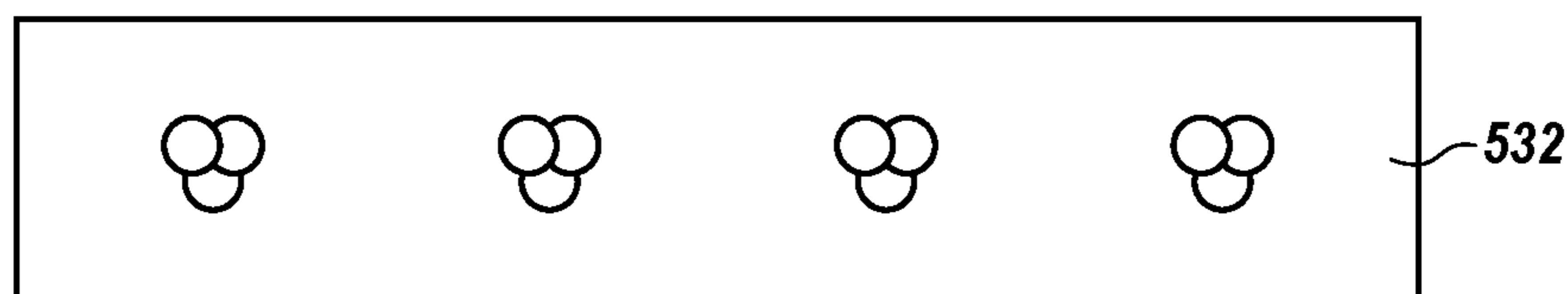


**FIG. 3**

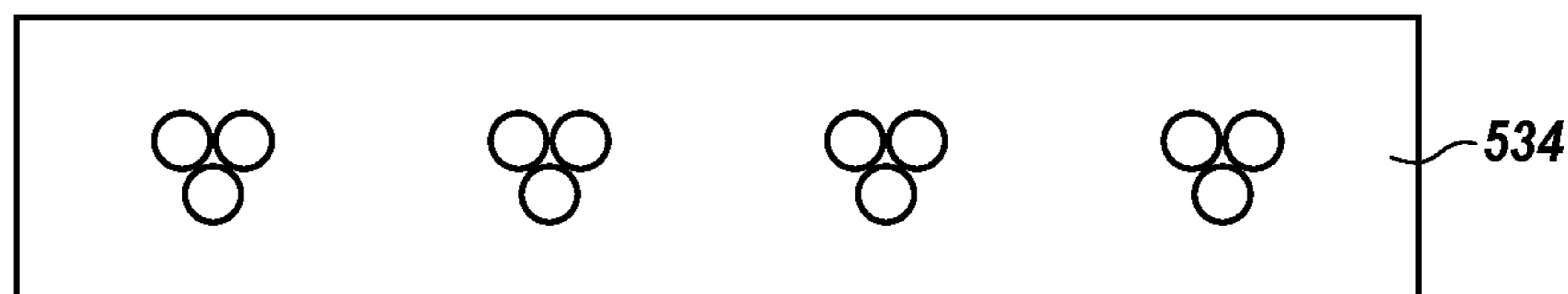




***FIG. 5A***

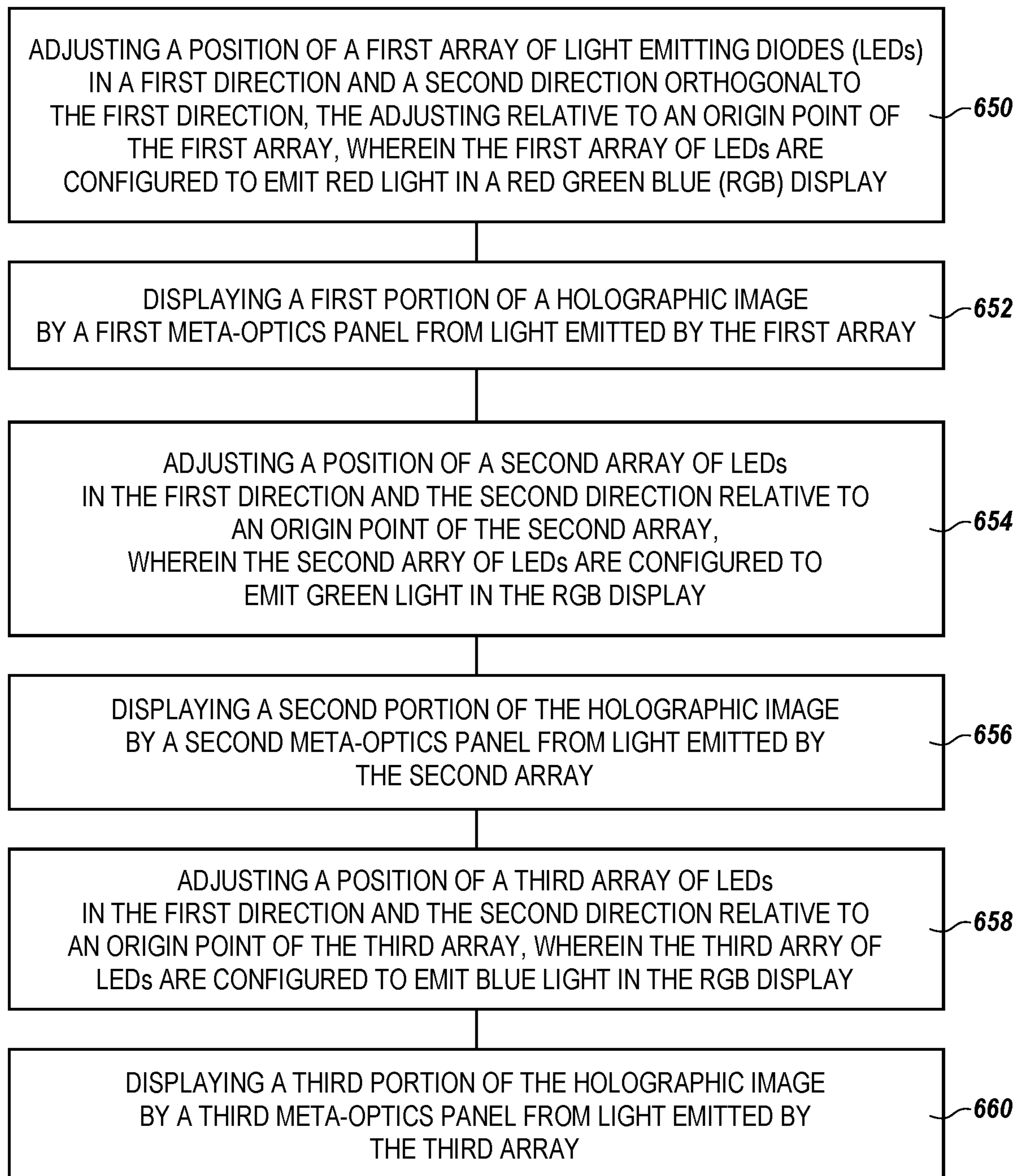


***FIG. 5B***



***FIG. 5C***



**FIG. 6**



## 1

**STACKED LIGHT EMITTING DIODE (LED)  
HOLOGRAM DISPLAY**

## PRIORITY INFORMATION

This application is a continuation of U.S. application Ser. No. 17/102,760, filed on Nov. 24, 2020, then contents of which are incorporated herein by reference.

## TECHNICAL FIELD

The present disclosure relates generally to apparatuses, non-transitory machine-readable media, and methods for a stacked light emitting diode (LED) hologram display.

## BACKGROUND

Images can be viewed on display screens. Display screens can be included in a computing device. A computing device is a mechanical or electrical device that transmits or modifies energy to perform or assist in the performance of human tasks. Examples include thin clients, personal computers, printing devices, laptops, mobile devices (e.g., e-readers, tablets, smartphones, etc.), internet-of-things (IoT) enabled devices, heads-up displays, augmented reality and virtual reality devices, and gaming consoles, among others. An IoT enabled device can refer to a device embedded with electronics, software, sensors, actuators, and/or network connectivity which enable such devices to connect to a network and/or exchange data. Examples of IoT enabled devices include mobile phones, smartphones, tablets, phablets, computing devices, implantable devices, vehicles, home appliances, smart home devices, monitoring devices, wearable devices, devices enabling intelligent shopping systems, among other cyber-physical systems.

A display screen can be included in a computing device, television monitor, computer monitor and can be used to view images and/or text. The display can be a touchscreen display that serves as an input device. When a touchscreen display is touched by a finger, digital pen (e.g., stylus), or other input mechanism, associated data can be received by the computing device. The touchscreen display may include pictures and/or words, among others that a user can touch to interact with the device.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a functional block diagram a stacked light emitting diode (LED) hologram display in accordance with a number of embodiments of the present disclosure.

FIG. 2 is a functional block diagram of a stacked light emitting diode (LED) hologram display including arrays of LEDs, meta-optics panels, and a number of actuators in accordance with a number of embodiments of the present disclosure.

FIG. 3 is a functional block diagram of a stacked light emitting diode (LED) hologram display including arrays of LEDs, a meta-optics panel, and a number of actuators in accordance with a number of embodiments of the present disclosure.

FIGS. 4A-4B are functional block diagrams in the form of an apparatus having a stacked light emitting diode (LED) hologram display including a controller in accordance with a number of embodiments of the present disclosure.

FIGS. 5A-5C illustrate packing schemes of a stacked light emitting diode (LED) hologram display in accordance with a number of embodiments of the present disclosure.

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FIG. 6 is flow diagram representing an example method for operating a stacked light emitting diode (LED) hologram display in accordance with a number of embodiments of the present disclosure.

## DETAILED DESCRIPTION

Embodiments of the present disclosure include apparatuses and methods for a stacked lighting emitting diode (LED) hologram display. A stacked LED hologram display can include a first array of LEDs that are configured to emit red light received by a meta-optics panel configured to display a first portion of a holographic image, a second array of LEDs that are configured to emit green light received by a meta-optics panel configured to display a second portion of a holographic image, and a third array of LEDs that are configured to emit blue light received by a meta-optics panel configured to display a third portion of a holographic image. The first, second, third arrays of LEDs can be configured to emit light on a number of meta-optics panels configured to produce (e.g., display) a holographic image (e.g., by shaping and enhancing the light emitted by the arrays). A pixel of the stacked LED display can comprise an LED from the first array, an LED from the second array, and an LED from the third array that are in a common row and column position of their respective array. For example, a pixel can be comprised of an LED in the first column and eight row of the first array, an LED in the first column and eight row of the second array, and an LED in the first column and eight row of the third array.

In a number of embodiments, the stacked LED hologram display can include a number of actuators configured to adjust a position of a first array of LEDs in a first direction (e.g., x direction) and a second direction orthogonal to the first direction (e.g., y direction), adjust a position of a second array of LEDs in the first direction and the second direction, and adjust a position of a third array of LEDs in the first direction and the second direction. The actuators can be configured to adjust the position of the arrays of LEDs in the first direction and the second direction to control a packing scheme of the pixels of the display. A packing scheme can refer to the position of the LEDs of a pixel relative to each other in the first direction and the second direction. For example, a pixel comprising a red LED, a green LED, and a blue LED can have a packing scheme where the LEDs completely overlap each other, partially overlap each other, and/or do not overlap each other. The position of the first array of LEDs in the first and second directions can allow the first array to emit light on a first meta-optics panel configured to produce a first portion of a holographic image. The position of the second array of LEDs in the first and second directions can allow the second array to emit light on a second meta-optics panel configured to produce a second portion of a holographic image. The position of the third array of LEDs in the first and second directions can allow the third array to emit light on a third meta-optics panel configured to produce a third portion of a holographic image.

In a number of embodiments, the stacked LED hologram display can include a number of actuators configured to adjust a position of each LED of a first array of LEDs in a first direction (e.g., x direction) and second direction (e.g., y direction) and an angle of rotation ( $\alpha$ ) around the x-axis, an angle of rotation ( $\beta$ ) around the y-axis, and an angle of rotation ( $\gamma$ ) around the z-axis. The number of actuators can adjust a position of each LED of a second array of LEDs in the first direction and the second direction and an angle of rotation ( $\alpha$ ) around the x-axis, an angle of rotation ( $\beta$ )



around the y-axis, and an angle of rotation ( $\gamma$ ) around the z-axis. The number of actuators can adjust a position of each LED of a third array of LEDs in the first direction and the second direction and an angle of rotation ( $\alpha$ ) around the x-axis, an angle of rotation ( $\beta$ ) around the y-axis, and an angle of rotation ( $\gamma$ ) around the z-axis. The actuators can be configured to adjust the position of the arrays of LEDs in the first direction and second direction to control a packing scheme of the pixels of the display and/or an angle at which light emitted from the LED arrays is received by a meta-optics panel. A packing scheme can refer to the position of the LEDs of a pixel relative to each other in the first direction and second direction. For example, a pixel comprising a red LED, a green LED, and a blue LED can have a packing scheme where the LEDs completely overlap each other, partially overlap each other, and/or do not overlap each other. The position of the LEDs in the first array of LEDs in the first and second directions and angles of rotation around the x, y, and z axes can allow the first array to emit light on a meta-optics panel configured to produce a first portion (e.g., red light) of a holographic image. The position of the LEDs in the second array of LEDs in the first and second directions and angles of rotation around the x, y, and z axes can allow the second array to emit light on the meta-optics panel configured to produce a second portion (e.g., green light) of the holographic image. The position of the LEDs in the third array of LEDs in the first and second directions and angles of rotation around the x, y, and z axes can allow the third array to emit light on the meta-optics panel configured to produce a third portion (e.g., blue light) of the holographic image.

In a number of embodiments, each of the LEDs in the stack of LED arrays can be individually controlled, activated, and deactivated. The LEDs can be individually controlled, activated, and deactivated to control power consumption of the device and/or control the intensity of the light emitted from each of the LEDs.

As used herein, designators such as “N,” “M,” etc., particularly with respect to reference numerals in the drawings, indicate that a number of the particular feature so designation can be included. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. As used herein, the singular forms “a,” “an,” and “the” can include both singular and plural referents, unless the context clearly dictates otherwise. In addition, “a number of,” “at least one,” and “one or more” (e.g., a number of memory devices) can refer to one or more memory devices, whereas a “plurality of” is intended to refer to more than one of such things. Furthermore, the words “can” and “may” are used throughout this application in a permissive sense (i.e., having the potential to, being able to), not in a mandatory sense (i.e., must). The term “include,” and derivations thereof, means “including, but not limited to.” The terms “coupled,” and “coupling” mean to be directly or indirectly connected physically or for access to and movement (transmission) of commands and/or data, as appropriate to the context. The terms “data” and “data values” are used interchangeably herein and can have the same meaning, as appropriate to the context.

The figures herein follow a numbering convention in which the first digit or digits correspond to the figure number and the remaining digits identify an element or component in the figure. Similar elements or components between different figures can be identified by the use of similar digits. For example, **104** can reference element “04” in FIG. 1, and a similar element can be referenced as **204** in FIG. 2. As will

be appreciated, elements shown in the various embodiments herein can be added, exchanged, and/or eliminated so as to provide a number of additional embodiments of the present disclosure. In addition, the proportion and/or the relative scale of the elements provided in the figures are intended to illustrate certain embodiments of the present disclosure and should not be taken in a limiting sense.

FIG. 1 is a functional block diagram a stacked light emitting diode (LED) display **100** in accordance with a number of embodiments of the present disclosure. Display **100** includes controller **110** (e.g., a processor, control circuitry, hardware, firmware, and/or software), a first array of LEDs **104-1**, a second array of LEDs **104-2**, a third array of LEDs **104-3**, a first meta-optics panel **106-1**, a second meta-optics panel **106-2**, and a third meta-optics panel **106-3**. First array **104-1**, second array **104-2**, and third array **104-3** can be configured in a stack and can be parallel to each other. For example, array **104-3** can be on top of array **104-2** and array **104-2** can be on top of array **104-1**. First meta-optics panel **106-1** can be positioned between array **104-1** and **104-2** and be configured to receive light from array **104-1**, second meta-optics panel **106-2** can be positioned between array **104-2** and **104-3** and be configured to receive light from array **104-2**, and third meta-optics panel **106-3** can be positioned above array **104-3** and be configured to receive light from array **104-3**. A number of embodiments, can include one meta-optics panel **106** that is positioned above array **104-3** and is configured to receive light from array **104-1**, **104-2**, and **104-3**.

First array **104-1**, second array **104-2**, and third array **104-3** can be micro-LED arrays, where each micro-LED can be controlled and provides light for a pixel of display **100**. First array **104-1** can be configured to emit red light, second array **104-2** can be configured to emit green light, and third array **104-3** can be configured to emit blue light, such that display **100** produces an image (e.g., a holographic image in a red green blue (RGB) format).

The display **100** may be a television display, a computer monitor display, and/or a touchscreen display of a mobile device, such as a smartphone, for example and be configured to display a holographic image (e.g., hologram). The controller **110** can be communicatively coupled to the LED arrays **104-1**, **104-2**, and **104-3** of display **100**. As used herein, “communicatively coupled” can include coupled via various wired and/or wireless connections between devices such that data can be transferred in various directions between the devices. The coupling need not be a direct connection, and in some examples, can be an indirect connection. Controller **110** can include hardware, firmware, and/or software to control the LED arrays **104-1**, **104-2**, and **104-3** of display **100**. Controller **110** can send signals to arrays **104-1**, **104-2**, and **104-3** to activate and/or deactivate the LEDs. LED arrays **104-1**, **104-2**, and **104-3** can include circuitry and electrodes such that each LED is controllable (e.g., addressable) by controller **110**. Controller **110** can individually activate and/or deactivate each LED of arrays **104-1**, **104-2**, and **104-3**.

In a number of embodiments, display **100** can received inputs from a camera, a computer, and/or an internet of things (IoT) device, among other input devices, to produce a holographic image. For example, a camera used during a medical procedure can provide an input to display **100** such that a holographic image of the portion of the body and medical instruments used during the medical procedure are displayed. Display **100** could also receive inputs to display holographic images that could provide instructions for assembling and/or fixing objects, a 3 dimensional view



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when arranging objects, and/or a 3-dimensional view indicating an inventory status (e.g., a refrigerator or pantry), among other inputs.

FIG. 2 is a functional block diagram of a stacked light emitting diode (LED) hologram display including arrays of LEDs, meta-optics panels, and a number of actuators in accordance with a number of embodiments of the present disclosure. FIG. 2 includes display an exploded view of LED arrays **204-1**, **204-2**, and **204-3** and meta-optics panels **206-1**, **206-2**, and **206-3** of display **200**. Each LED array **204-1**, **204-2**, and **204-3** can include a number of LEDs **205** arranged in row and columns. In FIG. 2, each LED array **204-1**, **204-2**, and **204-3** includes 16 LEDs arranged in 4 rows and 4 columns. LED arrays **204-1**, **204-2**, and **204-3** can have any number of rows and columns of LEDs and in a number of embodiments have thousands of rows and columns of LEDs. FIG. 2 includes 4 rows and 4 columns for ease of illustration.

In a number of embodiments, display **200** can include a number pixels, where an LED at a particular row and column position of each LED array **204-1**, **204-2**, and **204-3** comprise a pixel. For example, in FIGS. 2, a pixel of display **200** comprises LED **205-1** in row 4, column 2 of array **204-1**, LED **205-2** in row 4, column 2 of array **204-2**, and LED **205-3** in row 4, column 2 of array **204-3**. The pixel that includes LEDs **205-1**, **205-2**, and **205-3** can include light emitted from LEDs **205-1**, **205-2**, and **205-3**. The pixel that includes LEDs **205-1**, **205-2**, and **205-3** can emit light that is part of an RGB holographic image, where LED **205-1** can be configured to emit red light, LED **205-2** can be configured to emit green light, and LED **205-3** can be configured to emit blue light.

Display **200** can include a number of actuators **222-1** that are configured to move array **204-1** in the first direction (e.g., x direction) and a number of actuators **224-1** that are configured to move array **204-1** in the second direction (e.g., y direction). Display **200** can include a number of actuators **222-2** that are configured to move array **204-2** in the first direction (e.g., x direction) and a number of actuators **224-2** that are configured to move array **204-2** in the second direction (e.g., y direction). Display **200** can include a number of actuators **222-3** that are configured to move array **204-3** in the first direction (e.g., x direction) and a number of actuators **224-3** that are configured to move array **204-3** in the second direction (e.g., y direction). Actuators **222-1**, **224-1**, **222-2**, **224-2**, **222-3**, and **224-3** can be configured to move arrays **204-1**, **204-2**, and **204-3** to control the packing scheme of the LEDs of arrays **204-1**, **204-2**, and **204-3**. The packing scheme can be the position of an LED of a pixel relative to the other LEDs of the pixel. For example, actuators **222-1** can move array **204-1** to the right such that the LEDs in array **204-1** are offset in the first direction relative to the LEDs of array **204-2** and **204-3**. The packing scheme of the pixels can be controlled to control image properties of the holographic image displayed by display **200**. For example, the packing scheme can be changed to control the illumination intensity, brightness, color gamut, gray level, contrast, uniformity, resolution, saturation, white balance, and/or spectral sensitivity, among other image properties, of holographic images displayed by display **200**.

Meta-optics panel **206-1** can be configured to receive light from array **204-1** and be configured to display a first portion (e.g., red light) of a holographic image. Meta-optics panel can receive light from an array and transmit light through the panel to project a holographic image (e.g., by shaping and enhancing the light emitted by the array). Meta-optics panel **206-2** can be configured to receive light from array **204-2**

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and be configured to display a second portion (e.g., green light) of a holographic image. Meta-optics panel **206-3** can be configured to receive light from array **204-3** and be configured to display a third portion (e.g., blue light) of a holographic image. In a number of embodiments, where the actuators are configured to adjust the position of the arrays and/or LEDs in the first direction and the second direction, but not the angles of rotation (e.g., the arrays and/or LEDs have fixed angles of rotation), such as in FIG. 2, each array is associated with a meta-optics panel to produce a portion of a holographic image.

FIG. 3 is a functional block diagram of a stacked light emitting diode (LED) hologram display including arrays of LEDs, a meta-optics panel, and a number of actuators in accordance with a number of embodiments of the present disclosure. FIG. 3 includes display an exploded view of LED arrays **304-1**, **304-2**, and **304-3** of display **300** and meta-optics panel **306**. Each LED array **304-1**, **304-2**, and **304-3** can include a number of LEDs **305** arranged in row and columns. In FIG. 3, each LED array **304-1**, **304-2**, and **304-3** includes 16 LEDs arranged in 4 rows and 4 columns. LED arrays **304-1**, **304-2**, and **304-3** can have any number of rows and columns of LEDs and in a number of embodiments have thousands of rows and columns of LEDs. FIG. 3 includes 4 rows and 4 columns for ease of illustration.

In a number of embodiments, display **300** can include a number pixels, where an LED at a particular row and column position of each LED array **304-1**, **304-2**, and **304-3** comprise a pixel. For example, in FIGS. 3, a pixel of display **300** comprises LED **305-1** in row 4, column 2 of array **304-1**, LED **305-2** in row 4, column 2 of array **304-2**, and LED **305-3** in row 4, column 2 of array **304-3**. The pixel that includes LEDs **305-1**, **305-2**, and **305-3** can include light emitted from LEDs **305-1**, **305-2**, and **305-3**. The pixel that includes LEDs **305-1**, **305-2**, and **305-3** can emit light that is part of an RGB holographic image, where LED **305-1** can be configured to emit red light, LED **305-2** can be configured to emit green light, and LED **305-3** can be configured to emit blue light.

Display **300** can include a number of actuators **322-1** that are configured to individually move each LED of array **304-1** in the first direction (e.g., x direction), a number of actuators **324-1** that are configured to individually move each LED of array **304-1** in the second direction (e.g., y direction), and a number of actuators **326-1** that are configured to adjust an angle of rotation ( $\alpha$ ) around the x-axis, an angle of rotation ( $\beta$ ) around the y-axis, and an angle of rotation ( $\gamma$ ) around the z-axis for each LED of array **304-1**. The number of actuators **322-1** can be configured such that each LED of array **304-1** is coupled to one actuator of the number of actuators **322-1** and to individually control movement of each LED in the first direction. The number of actuators **324-1** can be configured such that each LED of array **304-1** is coupled to one actuator of the number of actuators **324-1** and to individually control movement of each LED in the second direction. The number of actuators **326-1** can be configured such that each LED of array **304-1** is coupled to one actuator of the number of actuators **326-1** and to individually control an angle of rotation ( $\alpha$ ) around the x-axis, an angle of rotation ( $\beta$ ) around the y-axis, and an angle of rotation ( $\gamma$ ) around the z-axis for each LED of array **304-1**.

Display **300** can include a number of actuators **322-2** that are configured to individually move each LED of array **304-2** in the first direction (e.g., x direction), a number of actuators **324-2** that are configured to individually move each LED of array **304-2** in the second direction (e.g., y



direction), and a number of actuators **326-2** that are configured to adjust an angle of rotation ( $\alpha$ ) around the x-axis, an angle of rotation ( $\beta$ ) around the y-axis, and an angle of rotation ( $\gamma$ ) around the z-axis for each LED of array **304-2**. The number of actuators **322-2** can be configured such that each LED of array **304-2** is coupled to one actuator of the number of actuators **322-2** and to individually control movement of each LED in the first direction. The number of actuators **324-2** can be configured such that each LED of array **304-2** is coupled to one actuator of the number of actuators **324-2** and to individually control movement of each LED in the second direction. The number of actuators **326-2** can be configured such that each LED of array **304-2** is coupled to one actuator of the number of actuators **326-2** and to individually control an angle of rotation ( $\alpha$ ) around the x-axis, an angle of rotation ( $\beta$ ) around the y-axis, and an angle of rotation ( $\gamma$ ) around the z-axis for each LED of array **304-2**.

Display **300** can include a number of actuators **322-3** that are configured to individually move each LED of array **304-3** in the first direction (e.g., x direction) and a number of actuators **324-3** that are configured to individually move each LED of array **304-3** in the second direction (e.g., y direction), and a number of actuators **326-3** that are configured to adjust an angle of rotation ( $\alpha$ ) around the x-axis, an angle of rotation ( $\beta$ ) around the y-axis, and an angle of rotation ( $\gamma$ ) around the z-axis for each LED of array **304-3**. The number of actuators **322-3** can be configured such that each LED of array **304-3** is coupled to one actuator of the number of actuators **322-3** and to individually control movement of each LED in the first direction. The number of actuators **324-3** can be configured such that each LED of array **304-3** is coupled to one actuator of the number of actuators **324-3** and to individually control movement of each LED in the second direction. The number of actuators **326-3** can be configured such that each LED of array **304-3** is coupled to one actuator of the number of actuators **326-3** and to individually control an angle of rotation ( $\alpha$ ) around the x-axis, an angle of rotation ( $\beta$ ) around the y-axis, and an angle of rotation ( $\gamma$ ) around the z-axis for each LED of array **304-3**.

Actuators **322-1**, **324-1**, **326-1**, **322-2**, **324-2**, **326-2**, **322-3**, **324-3**, and **326-3** can be configured to individually move each of the LEDs of arrays **304-1**, **304-2**, and **304-3** to control the packing scheme and angle of rotation of the pixels comprising the LEDs of arrays **304-1**, **304-2**, and **304-3**. The packing scheme can be the position of an LED of a pixel relative to the other LEDs of the pixel. For example, actuators **322-1** can move LED **305-1** to the right such that LED **305-1** in array **304-1** is offset in the first direction relative to the LED **305-2** of array **304-2** and LED **305-3** of array **304-3**. The packing scheme and angles of rotation around the x, y, and z axes can allow the first array to emit light on meta-optics panel **306** configured to produce a first portion (e.g., red light) of a holographic image. The position of the LEDs in the second array of LEDs in the first and second directions and angles of rotation around the x, y, and z axes can allow the second array to emit light on meta-optics panel **306** configured to produce a second portion (e.g., green light) of the holographic image. The position of the LEDs in the third array of LEDs in the first and second directions and angles of rotation around the x, y, and z axes can allow the third array to emit light on meta-optics panel **306** configured to produce a third portion (e.g., blue light) of the holographic image. The packing scheme of the pixels can be controlled to control image properties of the image displayed by display **300**. For

example, the packing scheme can be changed to control the brightness, color gamut, gray level, contrast, uniformity, resolution, saturation, white balance, and/or spectral sensitivity, among other image properties, of images displayed by display **300**. In a number of embodiments, where actuator are configured to control movement of each LED of the LED arrays in the first direction and second direction and control angles of rotation around the x, y, and z axes for each LED of the LED arrays, one meta-optics panel (e.g. panel **306** of FIG. **3**) can be configured to produce a holographic image with red light, green light, and blue light.

FIGS. **4A-4B** are functional block diagrams in the form of an apparatus having a stacked light emitting diode (LED) hologram display including a controller in accordance with a number of embodiments of the present disclosure. In FIG. **4A**, display **400** can include substrate **412**, first array of LEDs **404-1**, second array of LEDs **404-2**, third array of LEDs **404-3**, first meta-optics panel **406-1**, second meta-optics panel **406-2**, third meta-optics panel **406-3**, cover **414**, and controller **410**. Display **400** can include first array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3** formed on substrate **412**. First array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3** can be stacked on each other and configured such that light emitted from the first array of LEDs **404-1** is directed to first meta-optics panel **406-1** that is configured to display a first portion of a holographic image, light emitted from the second array of LEDs **404-2** is directed to second meta-optics panel **406-2** that is configured to display a second portion of a holographic image, and light emitted from the third array of LEDs **404-3** is directed to third meta-optics panel **406-3** that is configured to display a third portion of a holographic image. Cover **414** can be comprised of glass and other materials, such as polarizers. Cover **414** can protect the arrays of LEDs from damage.

In FIG. **4B**, display **400** can include substrate **412**, first array of LEDs **404-1**, second array of LEDs **404-2**, third array of LEDs **404-3**, meta-optics panel **406**, cover **414**, and controller **410**. Display **400** can include first array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3** formed on substrate **412**. First array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3** can be stacked on each other and configured such that light emitted from the first array of LEDs **404-1** is directed to meta-optics panel **406** that is configured to display a first portion of a holographic image, light emitted from the second array of LEDs **404-2** is directed to meta-optics panel **406** that is configured to display a second portion of a holographic image, and light emitted from the third array of LEDs **404-3** is directed to meta-optics panel **406** that is configured to display a third portion of a holographic image. First array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3** can be moved by actuators to control movement of each LED of the LED arrays in the first direction (e.g., x direction) and second direction (e.g., y direction) and control angles of rotation around the x, y, and z axes for each LED of the LED arrays and meta-optics panel **406** can be configured to produce a holographic image with red light, green light, and blue light from the first array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3**, respectively.

First array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3** can be coupled to controller **410** and can be configured to receive signals from controller **410** to activate and deactivate the LEDs. In a number of embodiments, controller **410** can send a signal or signals to individually activate and/or deactivate each LED of first



array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3**. For example, controller **410** can send signals to the first array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3** such that only a portion of the LEDs of the first array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3** are activated. The controller can activate only a portion of the LEDs of first array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3** to control the power consumption of display **400**. Also, controller **410** can send signals with various magnitudes to control the light emitted by the LEDs of the first array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3**. The signals and the magnitude of the signals sent by controller **410** to the first array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3** can control the illumination intensity, brightness, color gamut, gray level, contrast, uniformity, resolution, saturation, white balance, and/or spectral sensitivity, among other image properties, of holographic images displayed by display **400**. Controller **410** can monitor the properties of the holographic image that is displayed by display **400** and change the signals sent to the first array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3** to change and/or improve the properties of the holographic image displayed by display **400**. For example, controller **410** can change the brightness of the images based on the environment where the image is being displayed. Also, controller **410** can change signals sent to the first array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3** to improve image quality. Controller **410** can also receive user input to change the signals sent to the first array of LEDs **404-1**, second array of LEDs **404-2**, and third array of LEDs **404-3**.

FIGS. **5A-5C** illustrate packing schemes of a stacked light emitting diode (LED) display in accordance with a number of embodiments of the present disclosure. FIGS. **5A-5C** illustrates packing schemes of 4 pixels, pixel **540-1**, pixel **540-2**, pixel **540-3**, and pixel **540-4**. Pixels **540-1**, **540-2**, **540-3**, and **540-4** can include LEDs from a row of arrays of LEDs, such as a first row of arrays **204-1**, **204-2**, and **204-3** of FIG. **2** or a first row of arrays of **304-2**, **304-2**, and **304-3** of FIG. **3**, for example. FIGS. **5A-5C** illustrate a top down view of pixels **540-1**, **540-2**, **540-3**, and **540-4**, such the pixels comprising the LEDs from arrays of LEDs are stacked on each other.

FIG. **5A** includes a packing scheme where the LEDs of pixels **540-1**, **540-2**, **540-3**, and **540-4** are not offset and completely overlap. In FIG. **5A**, pixel **540-1** includes LED **505-1-3** from a third array of LEDs and an LED from a second array (not shown due to the packing scheme not including an offset) and an LED from a first array (not shown due to the packing scheme not including an offset). Pixel **540-2** includes LED **505-2-3** from a third array of LEDs and an LED from a second array (not shown due to the packing scheme not including an offset) and an LED from a first array (not shown due to the packing scheme not including an offset). Pixel **540-3** includes LED **505-3-3** from a third array of LEDs and an LED from a second array (not shown due to the packing scheme not including an offset) and an LED from a first array (not shown due to the packing scheme not including an offset). Pixel **540-4** includes LED **505-4-3** from a third array of LEDs and an LED from a second array (not shown due to the packing scheme not including an offset) and an LED from a first array (not shown due to the packing scheme not including an offset). In a number of embodiments, a controller can send signals to actuators (e.g., actuators **222** and **224** in FIGS. **2** and **322**

and **324** in FIG. **3**) to move arrays and/or LEDs such that the pixels have a packing scheme that is aligned and there is no offset of the LEDs in the first or second direction (e.g., x or y direction).

FIG. **5B** includes a packing scheme where the LEDs of pixels **540-1**, **540-2**, **540-3**, and **540-4** are offset and partially overlap. In FIG. **5B**, pixel **540-1** includes LED **505-1-1** from a first array of LEDs, LED **505-1-2** from a second array of LEDs that is offset in the first direction (e.g., x direction) and second direction (e.g., y direction) relative to LED **505-1-1**, and LED **505-1-3** from a third array of LEDs that is offset in the first direction and second direction relative to LED **505-1-1**, such that LEDs **505-1-1**, **505-1-2**, and **505-1-3** partially overlap each other. Pixel **540-2** includes LED **505-2-1** from a first array of LEDs, LED **505-2-2** from a second array of LEDs that is offset in the first direction and second direction relative to LED **505-2-1**, and LED **505-2-3** from a third array of LEDs that is offset in the first direction and second direction relative to LED **505-2-1**, such that LEDs **505-2-1**, **505-2-2**, and **505-2-3** partially overlap each other. Pixel **540-3** includes LED **505-3-1** from a first array of LEDs, LED **505-3-2** from a second array of LEDs that is offset in the first direction and second direction relative to LED **505-3-1**, and LED **505-3-3** from a third array of LEDs that is offset in the first direction and second direction relative to LED **505-3-1**, such that LEDs **505-3-1**, **505-3-2**, and **505-3-3** partially overlap each other. Pixel **540-4** includes LED **505-4-1** from a first array of LEDs, LED **505-4-2** from a second array of LEDs that is offset in the first direction and second direction relative to LED **505-4-1**, and LED **505-4-3** from a third array of LEDs that is offset in the first direction and second direction relative to LED **505-4-1**, such that LEDs **505-4-1**, **505-4-2**, and **505-4-3** partially overlap each other. In a number of embodiments, a controller can send signals to actuators (e.g., actuators **222** and **224** in FIGS. **2** and **322** and **324** in FIG. **3**) to move arrays and/or LEDs such that the pixels have a packing scheme where there is offset of the LEDs in the x and/or y direction such that the LEDs partially overlap.

FIG. **5C** includes a packing scheme where the LEDs of pixels **540-1**, **540-2**, **540-3**, and **540-4** are offset and do not overlap. In FIG. **5B**, pixel **540-1** includes LED **505-1-1** from a first array of LEDs, LED **505-1-2** from a second array of LEDs that is offset in the first direction (e.g., x direction) and second direction (e.g., y direction) relative to LED **505-1-1**, and LED **505-1-3** from a third array of LEDs that is offset in the first direction and second direction relative to LED **505-1-1**, such that LEDs **505-1-1**, **505-1-2**, and **505-1-3** do not overlap each other. Pixel **540-2** includes LED **505-2-1** from a first array of LEDs, LED **505-2-2** from a second array of LEDs that is offset in the first direction and second direction relative to LED **505-2-1**, and LED **505-2-3** from a third array of LEDs that is offset in the first direction and second direction relative to LED **505-2-1**, such that LEDs **505-2-1**, **505-2-2**, and **505-2-3** partially overlap each other. Pixel **540-3** includes LED **505-3-1** from a first array of LEDs, LED **505-3-2** from a second array of LEDs that is offset in the first direction and second direction relative to LED **505-3-1**, and LED **505-3-3** from a third array of LEDs that is offset in the first direction and second direction relative to LED **505-3-1**, such that LEDs **505-3-1**, **505-3-2**, and **505-3-3** do not overlap each other. Pixel **540-4** includes LED **505-4-1** from a first array of LEDs, LED **505-4-2** from a second array of LEDs that is offset in the first direction and second direction relative to LED **505-4-1**, and LED **505-4-3** from a third array of LEDs that is offset in the first direction and second direction relative to LED **505-4-1**, such that



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LEDs 505-4-1, 505-4-2, and 505-4-3 do not overlap each other. In a number of embodiments, a controller can send signals to actuators (e.g., actuators 222 and 224 in FIGS. 2 and 322 and 324 in FIG. 3) to move arrays and/or LEDs such that the pixels have a packing scheme where there is offset of the LEDs in the first and/or second direction such that the LEDs do not overlap.

FIG. 6 is flow diagram representing an example method for operating a stacked light emitting diode (LED) hologram display in accordance with a number of embodiments of the present disclosure. At step 650, the method can include adjusting a position of a first array of light emitting diodes (LEDs) in a first direction and a second direction orthogonal to the first direction, the adjusting relative to an origin point of the first array, wherein the first array of LEDs are configured to emit red light in a red green blue (RGB) hologram display.

At step 652, the method can include displaying a first portion of a holographic image by a first meta-optics panel from light emitted by the first array.

At step 654, the method can include adjusting a position of a second array of LEDs in the first direction and the second direction relative to an origin point of the second array, wherein the second array of LEDs are configured to emit green light in the RGB display.

At step 656, the method can include displaying a second portion of the holographic image by a second meta-optics panel from light emitted by the second array.

At step 658, the method can include adjusting a position of a second array of LEDs in the first direction and the second direction relative to an origin point of the third array, wherein the third array of LEDs are configured to emit blue light in the RGB display.

At step 660, the method can include displaying a third portion of the holographic image by a third meta-optics panel from light emitted by the third array, wherein the first, second, and third arrays are stacked on each other.

The method can also include adjusting the position of the first array of LEDs in the first direction and the second direction offsets the first array of LEDs relative to the second and third array of LEDs, adjusting the position of the second array of LEDs in the first direction and the second direction offsets the second array of LEDs relative to the first and third array of LEDs, and adjusting the position of the third array of LEDs in the first direction and the second direction offsets the third array of LEDs relative to the first and second array of LEDs.

The method can include providing signals to the first array of LEDs, the second array of LEDs, and the third array of LEDs to change an illumination intensity of the LEDs and providing signals to the first array of LEDs, the second array of LEDs, and the third array of LEDs to deactivate at least a portion of one of the first array of LEDs, the second array of LEDs, and the third array of LEDs.

Although specific embodiments have been illustrated and described herein, those of ordinary skill in the art will appreciate that an arrangement calculated to achieve the same results can be substituted for the specific embodiments shown. This disclosure is intended to cover adaptations or variations of one or more embodiments of the present disclosure. It is to be understood that the above description has been made in an illustrative fashion, and not a restrictive one. Combination of the above embodiments, and other embodiments not specifically described herein will be apparent to those of skill in the art upon reviewing the above description. The scope of the one or more embodiments of the present disclosure includes other applications in which

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the above structures and processes are used. Therefore, the scope of one or more embodiments of the present disclosure should be determined with reference to the appended claims, along with the full range of equivalents to which such claims are entitled.

In the foregoing Detailed Description, some features are grouped together in a single embodiment for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the disclosed embodiments of the present disclosure have to use more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed embodiment. Thus, the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separate embodiment.

What is claimed is:

1. A method, comprising:

adjusting a position of a first array of light emitting diodes (LEDs) relative to an origin point of the first array, wherein the first array of LEDs are configured to emit red light in a red green blue (RGB) hologram display; displaying a first portion of a holographic image by a first meta-optics panel from light emitted by the first array; adjusting a position of a second array of LEDs relative to an origin point of the second array, wherein the second array of LEDs are configured to emit green light in the RGB display; displaying a second portion of the holographic image by a second meta-optics panel from light emitted by the second array; adjusting a position of a second array of LEDs relative to an origin point of the third array, wherein the third array of LEDs are configured to emit blue light in the RGB display and; and displaying a third portion of the holographic image by a third meta-optics panel from light emitted by the third array, wherein the first, second, and third arrays are stacked on each other.

2. The method of claim 1, further comprising adjusting the position of the first array of LEDs in a first direction and a second direction offsets the first array of LEDs relative to the second and third array of LEDs.

3. The method of claim 1, further comprising adjusting the position of the second array of LEDs in a first direction and a second direction offsets the second array of LEDs relative to the first and third array of LEDs.

4. The method of claim 1, further comprising adjusting the position of the third array of LEDs in a first direction and a second direction offsets the third array of LEDs relative to the first and second array of LEDs.

5. The method of claim 1, wherein the first array of LEDs, the second array of LEDs, and the third array of LEDs are parallel to each other at a fixed angle.

6. The method of claim 1, further comprising providing signals to the first array of LEDs, the second array of LEDs, and the third array of LEDs to change an illumination intensity of the LEDs.

7. The method of claim 1, further comprising providing signals to the first array of LEDs, the second array of LEDs, and the third array of LEDs to deactivate at least a portion of one of the first array of LEDs, the second array of LEDs, and the third array of LEDs.

8. An apparatus, comprising:

a first array of light emitting diodes (LED), wherein each LED of the first array are configured to emit red light received by a first meta-optics panel configured to



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- display a first portion of a holographic image and wherein the first array is coupled to a controller:
- a second array of LEDs, wherein each LED of the second array are configured to emit green light received by a second meta-optics panel configured to display a second portion of the holographic image and wherein the second array is coupled to the controller; and
- a third array of LEDs, wherein each LED of the third array are configured to emit blue light received by a third meta-optics panel configured to display a third portion of the holographic image, wherein the third array is coupled to the controller, and wherein the controller is configured to:
- send a first number of signals to a first actuator configured to move the first array, send a second number of signals to a second actuator to move the second array, and send a third number of signals to move the third array, wherein moving the first array, the second array, and the third array controls a packing scheme of the first, second, and third arrays.
9. The apparatus of claim 8, wherein the first actuator is configured to move the first array to offset the LEDs of the first array relative to the LEDs of the second and third arrays.
10. The apparatus of claim 8, wherein the second actuator is configured to move the second array to offset the LEDs of the second array relative to the LEDs of the first and third arrays.
11. The apparatus of claim 8, wherein the third actuator is configured to move the third array to offset the LEDs of the third array relative to the LEDs of the first and second arrays.
12. The apparatus of claim 8, wherein the first, second, and third actuators are configured to move the first, second and third arrays in a first direction and a second direction to change the packing scheme of the first, second, and third arrays that are stacked on each other.
13. The apparatus of claim 8, wherein the control circuitry is configured to provide signals to the first, second, and third arrays to change illumination intensity of the apparatus by activating at least a portion of the first, second, and third arrays.
14. The apparatus of claim 8, wherein the control circuitry is configured to provide signals to the first, second, and third arrays to control power consumption of the apparatus by activating at least a portion of the first, second, and third arrays.
15. An apparatus, comprising:  
a first array of light emitting diodes (LED), wherein each LED of the first array are configured to emit red light received by a meta-optics panel configured to display a

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- first portion of a holographic image and wherein the first array is coupled to a controller:
- a second array of LEDs, wherein each LED of the second array are configured to emit green light received by the meta-optics panel configured to display a second portion of the holographic image and wherein the second array is coupled to the controller; and
- a third array of LEDs, wherein each LED of the third array are configured to emit blue light received by the meta-optics panel configured to display a third portion of the holographic image, wherein the third array is coupled to the controller, wherein the first, second, and third array are stacked on each other, and wherein the controller is configured to:
- send a first number of signals to a first number of actuators configured to move each of the LEDs in the first array and rotate each of the LEDs in the first array,
- send a second number of signals to a second number of actuators to move each of the LEDs in the second array and rotate each of the LEDs in the second array, and
- send a third number of signals to a third number of actuators configured to move each of the LEDs in the third array and rotate each of the LEDs in the third array.
16. The apparatus of claim 15, wherein the control circuitry is configured to send a fourth number of signals to control intensity of each of the LEDs of the first, second, and third arrays.
17. The apparatus of claim 15, wherein the control circuitry is configured to send a fifth number of signals to turn on a portion of the LEDs of the first, second, and third arrays.
18. The apparatus of claim 15, wherein a position with respect to a first direction and a second direction of each LED of the first array overlaps with a position with respect to the first direction and second direction of each LED of the second array.
19. The apparatus of claim 15, wherein first, second, and third number of signals can be controlled by user input.
20. The apparatus of claim 15, wherein the first number of signals, the second number of signals, and the third number of signals are configured to control a packing scheme of the first, second and third arrays.

\* \* \* \* \*